The Caribbean Ocean plateau

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Introduction

This webpage presents a brief summary of the Caribbean plateau in the context of the regional geology of middle America (Figure 1; for a more comprehensive description and discussion, see also James, 2007). Papers on the plateau tend to concern themselves with its geochemistry (*e.g., Kerr et al.*, 2003) or seismic structure (*Diebold & Driscoll*, 1999). There is rarely comprehensive discussion of its regional geological context. At best, discussions are tied to the paradigm that derives the Caribbean plate from the Pacific (*e.g., Pindell & Barrett*, 1990, *Pindell et al.*, 1998). This paradigm invokes plate migration of thousands of kilometres, major rotation (up to 80°) of the large continental blocks of Maya and Chortis, reversal of ocean arc subduction, major rotation of arc segments (90°), slab roll-back in a variety of directions, burial of continental fragments to 80 km depth followed by exhumation during strike-slip, a plate boundary jump from Cuba to the Cayman Trench and inter- or back-arc spreading between the Aves Ridge and the Lesser Antilles.

This model is extremely complex. Many of its processes lack supporting data and many existing data are ignored or used selectively. It continues to become increasingly complex and its proponents tend to fail to address arguments against it (*Pindell et al.*, 2006). The alternative theory, that the Caribbean plate formed in place between separating North and South America, is supported by a minority of workers only, despite the fact that it accounts for all regional data in the context of simple geological evolution (*e.g., James*, 2005, 2006).

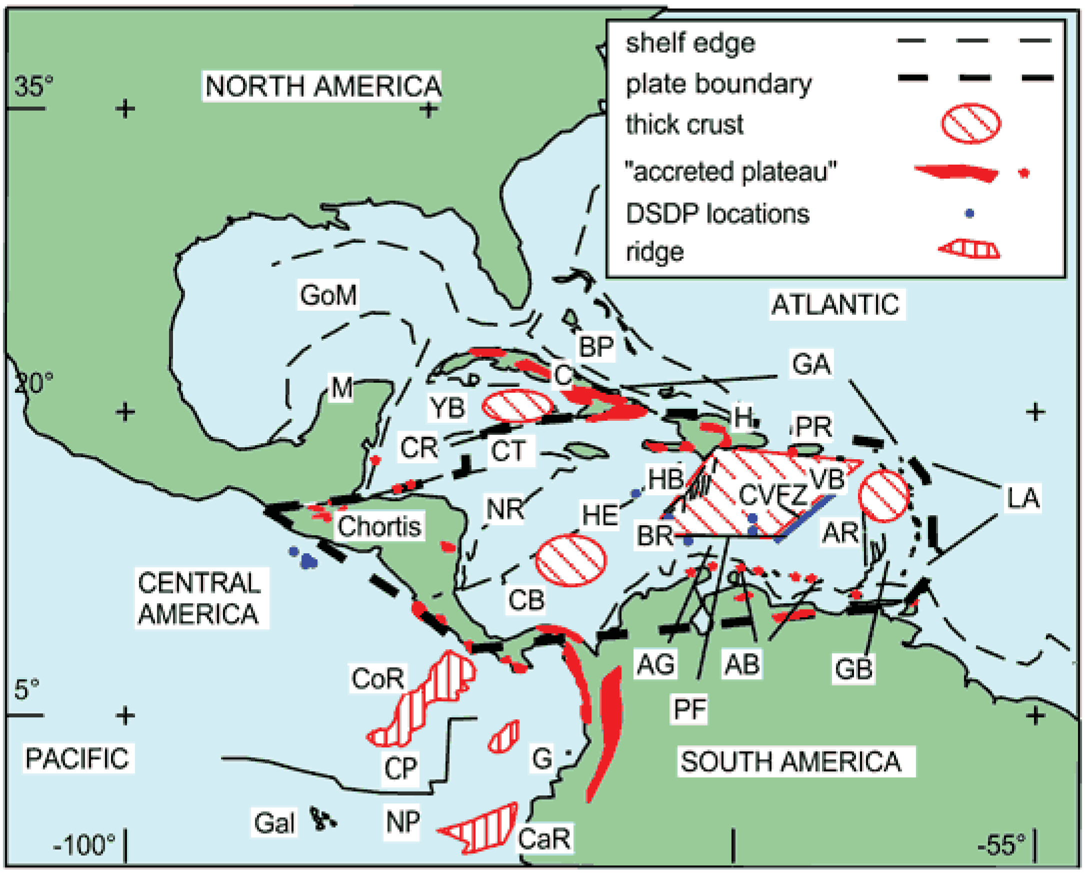

Figure 1. Middle America, AB – Aruba-Blanquilla, AR - Aves Ridge, BR - Beata Ridge, C – Cuba, CB – Colombia Basin, CP – Cocos plate, CR – Cayman Ridge, CT – Cayman Trough, G – Gorgona Island, GA – Greater Antilles, Gal – Galapagos Islands, GB – Grenada Basin, GoM – Gulf of Mexico, HE – Hess Escarpment, LA – Lesser Antilles, M – Maya, NP – Nazca plate, NR – Nicaragua Rise, VB – Venezuela Basin, YB – Yucatán Basin. Locations of Mesozoic plateau rocks in red (after Donnelly et al., 1990). The "original" Caribbean plateau (rhomoboid area) lies in the western Venezuela Basin, centred on the Beata Ridge and bounded to the SE by the Central Venezuelan FZ (blue). Accreted elements distributed around the area are commonly attributed to the plateau, though many clearly lie on different plates. Thick crust also occurs in the Yucatán and Grenada basins.

Caribbean geology, distributed over many different countries and islands, appears to be complex. Documentation ranges from good, in highly explored, contiguous areas in northern South America, to poor or absent in remote areas of tropical vegetation cover and weathering. There are no recognised oceanic spreading anomalies or fractures to indicate the age or tectonic origin of Caribbean plate crust. The only spreading ridge in the whole of Middle America lies in the centre of the Cayman Trough, which is a large, plate-boundary pull-apart.

Geophysical investigations show that parts of the Caribbean plate are much thicker than normal oceanic crust and have a different seismic velocity structure (*Officer et al.*, 1957). This thick crust is described as an oceanic plateau (*Donnelly*, 1973). The "original" plateau (rhomboid area in Figure 1) was a 20-km-thick area in the western part of the Venezuela Basin. Over time this has become linked to similar crust in the Colombia Basin and oceanic crust accreted around the plate margins. The assemblage is regarded as the best exposed oceanic plateau in the world (*Kerr et al.*, 1997).

The prevailing Pacific/plume model

The prevailing model holds that Caribbean crust formed in the Pacific (*e.g., Pindell & Barrett*, 1990). and thickened into a plateau over a hotspot or mantle plume (*e.g., Kerr et al.*, 2003). In this model, the plate migrated eastward between the Americas. On its way it collided with and choked a west-facing inter-oceanic subduction arc, causing metamorphism, reversal of subduction direction and a change in arc chemistry from primitive to calc-alkaline. The arc was then pushed in front of the plateau into the area between the Americas. Its northern and southern parts rotated and accreted along the Greater Antilles and northern South America, where volcanism ceased. The Lesser Antilles are the active remnants of the arc, marking subduction of Atlantic oceanic crust from the east. The continental Caribbean component, Chortis in the north west, was accreted after the plate entered between the Americas.

Two regional seismic reflections, A" and B", are seen across the Caribbean. DSDP/ODP drilling showed that A" marks the top of a middle-Eocene chert-limestone section below unconsolidated sediments. Horizon B" is smooth over the plateau and rough to the southeast. Smooth B" ties to 90 – 88 Ma basalts sampled by drilling (*Saunders et al.*, 1973) and these are interpreted to indicate voluminous plateau volcanism over a short period. Rough B" has never been penetrated. It has anormal oceanic crustal signature but its thickness of only around 3.5 km indicates extension (*Diebold & Driscoll*, 1999).

The "original" plateau has abrupt, linear NW and SE margins, both trending NE. The NW margin of the Beata Ridge drops down to the normal oceanic crust of the Haiti Basin by as much as 3,500 m. The SE margin – the Central Venezuelan Fault Zone (*Biju-Duval et al.*, 1978) is marked by a change in B" character from smooth to rough (*Talwani et al.*, 1977) .

Seismic data reveal the internal structure of the plateau. NE trending highs are flanked by at least two levels of dipping reflections. The architecture has been interpreted as large wedges of flows or sills sourced by highs which are built of vertical dykes (*Diebold & Driscoll*, 1999). The southeastern boundary of the plateau – the Central Venezuelan Fault Zone - is a major fault that bounds one of these wedges. The Moho drops abruptly across this fault. Diapiric features penetrating the sea floor above the plateau are interpreted to be volcanoes (*Diebold & Driscoll*, 1999).

The alternative model

There are only six DSDP/ODP sample sites on the Caribbean plateau and they penetrate only the top of a 20-km-thick section. Two other sites are located on the Hess Escarpment and in the Colombia Basin. Accreted plate margin rocks suggest that oceanic basalts formed also at around 120 Ma and that magmatism was continuous from the Albian to the Cenomanian or Campanian (*e.g. Beets et al.*, 1977; *Maurasse et al.,* 1979). The magmatism that thickened the plateau above the continental fragments was thus not a single extrusive event of short duration.

Great similarity in form and tectonic location between the Caribbean, and the Scotia and Banda plates indicates common origins (*James*, 2006). The latter two plates have calibrated magnetic anomalies and they are known to have formed in place by back-arc spreading. Scotia and Banda spreading changed location and orientation with time. Both plates are rimmed by distributed continental fragments. Banda is also known to carry "internal" continental fragments (*Milsom*, 2007) and Scotia may do so also (*Barker*, 2001).

Crustal thicknesses of 30 or more kilometres (seismic, gravity) and continental densities (gravity), quartz sands, ancient zircons and continental chemical signal in Cretaceous arc rocks and abundant silica-rich ignimbrites, andesites and tonalites argue for the presence of continental fragments around the Caribbean as well (*James*, 2007a, b).

They lie beneath the Nicaragua Rise, throughout Central America and below the Greater Antilles/northern Lesser Antilles, hidden below obducted oceanic/arc rocks and Cenozoic limestones and volcanic rocks.

The NE tectonic grain of the Caribbean plateau is attributed to underlying basement highs, which give rise to magnetic lineations over the area (*e.g., Diebold & Driscoll*, 1999). However, the origin of the trend is rarely discussed in papers. The plateau shares its structural grain with its continental neighbours, North and South America, the Chortis and Maya blocks, the Yucatán and (northern) Grenada basins and the distal parts of the Cayman Trench ([*James*, 2006]). Onshore geology shows that the regional NE tectonic grain is inherited from Proterozoic – Palaeozoic trends, reactivated by Triassic-Jurassic rifting during Pangean break up (Figure 2). In the whole of middle America there is no trace of the radial pattern expected above a plume.

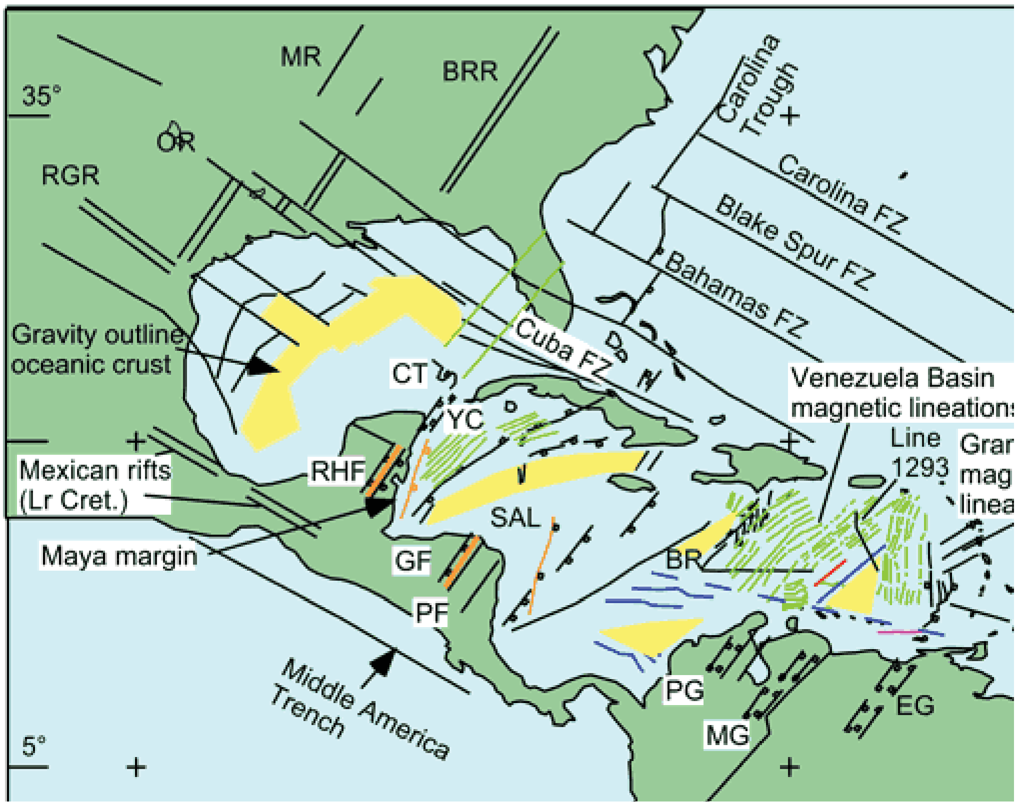

Figure 2. Middle America is bracketed by N60°W fractures (Cuba Fz., Middle America Trench) and shows in internal regional tectonic pattern of N35°E and N60°W faults. They reflect Triassic-Jurassic rifting and Jurassic-Cretaceous drifting. The Caribbean plate shares this regional pattern and shows no radial signature as expected of a plume. The red line marks the mapped SE limit of Caribbean plateau–the Central Venezuela FZ. Green lines are published magnetic anomalies. Blue lines are additional lineaments noted here. The NE trend over the "plateau" area reflects basement structures. Anomalies in the Yucatán Basin might have the same origin Magnetic anomalies in the east, parallel to the Aves Ridge, suggest that it was a back arc spreading centre, analogous to the East Scotia Ridge. BR - Beata Ridge, BRR - Blue Ridge Rift, CT - Catoche Tongue, EG - Espino Graben, GF - Guayape F., MG - Mérida Graben, MiG - Mississippi Graben, OR - Oachita Rift, PF- Patuca F., PG - Perijá Graben, RGR - Río Grande Rift, RHF - Río Hondo F., SAL - San Andrés Lineament, TF - Ticul F., TG - Takutu Graben, TT - Texas Transform, YC- Yucatán Channel.

The tectonic trend links the Yucatán Peninsula to Florida, across the SE Gulf of Mexico (*Gough*, 1967). Here, DSDP drilling and seismic data show Triassic/older basement blocks flanked by wedges of Jurassic sediments, evaporites and igneous flows/sills, overlain by Cretaceous carbonates, a regional middle – upper Cretaceous hiatus and Cenozoic sediments (*Phair & Buffler*, 1983).

The seismic architecture and the NE trend of the Caribbean plateau suggest that it shared this Gulf of Mexico history. Rather than being a simple large igneous province it consists of extended Triassic/older continental crustal blocks, flanked by Jurassic wedges of sediments, volcaniclastics/flows overlain by basaltic flows. Outcropping equivalents of these are vesicular, interbedded with sediments bearing shallow water fauna and show erosion and palaeosol development. Smooth Horizon B" could be subaerial "continental" basalt. Rough Horizon B" could be its oceanic equivalent, the product of extreme continental extension and serpentinization of upper mantle. That would mean a Late Cretaceous age for the SE Venezuela Basin.

If Jurassic sediments are present on the plateau, they might include salt. Seismic features interpreted as volcanoes push up sea floor sediments and are flanked by rim synclines; they do not show cone build-up. Perhaps some are salt domes, similar to the Sigsbee/Campeche Knolls (Jurassic salt) that rise above the floor of the Gulf of Mexico.

Summary

The alternative interpretation of the Caribbean plateau and the Caribbean plate contrasts radically with conventional ideas. It implies that perhaps as little as 20% of Middle America crust is oceanic (as in the Gulf of Mexico). What little oceanic crust there is, formed by back-arc spreading ranging in age from Jurassic to late Cretaceous with the locus of spreading migrating from the Gulf of Mexico to the Yucatán, Colombia, Venezuela and Grenada basins.

If correct, this interpretation totally negates a Pacific origin for the Caribbean plate and the theory that the Caribbean plateau formed above a plume there. It significantly modifies models that see the plate forming between the Americas. It has important implications for studies that seek to distinguish goechemically and isotopically between plume-derived large igneous provinces, inter-oceanic and continental volcanic arcs, and for hydrocarbon exploration in the area.

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